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Deformation driven by deep and distant structures: influence of a mantle lithosphere suture in arcuate orogen development

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Mantle lithosphere heterogeneities are often overlooked as a genesis of crustal-scale deformation. Our study analyzes the role of sub-crustal heterogeneities in generating orogenic crustal deformation through numerical models. Using the open-source geodynamics code ASPECT, we implement 3D continental shortening in the presence of mantle lithosphere suture zones and inherited crustal structures. The study presents a suite of models analyzing perpendicular and oblique compression, suture zone geometry, and lithosphere strengthening. We find that a weak mantle lithosphere suture zone can generate crustal deformation at a distance, overriding most shallowed inherited structures. In the three-dimensional models the deep suture zones produce curved orogens and basins.

Our models are compared to the arcuate Ouachita orogen in the southern United States, which underwent a ‘soft’ continental collision. Deep seismic imaging highlights a mantle lithosphere suture zone in the Ouachita region, with crustal deformation projected from it. The crustal tectonics derived from our models compares well with the available lithosphere-scale imaging of the region. The numerical modelling presented here offers an alternative hypothesis to the tectonic history of the Ouachita orogeny, with previous studies having focused exclusively on crustal structures. This study further demonstrates the possible role of the mantle lithosphere in controlling crustal structure and highlights the need to consider deeper processes when interpreting tectonic evolution.